The effect of vine spacing on water use efficiency

M.G. McCarthy

Michael McCarthy is Senior Research Officer, Viticulture, South Australian Department of Primary Industries (Agriculture), Nuriootpa

Abstract

A demonstration of vine planting density planted in Coonawarra in 1985 and a planting density rootstock experiment planted in the Barossa Valley in 1986 have both highlighted the consistently higher yields per hectare from high density plantings. At both sites the additional yield has been achieved without any additional irrigation during the growing season. Plant density has little effect on fruit maturity. Monitoring of soil water depletion with a neutron probe indicated little difference in soil water extraction across vine rows of different widths. It is hypothesized that high density vines result in significant vineyard floor shading which in turn reduces soil evaporation.

Introduction

At the Seventh Australian Wine Industry Technical Conference in 1989, preliminary data were presented (McCarthy 1990) on some aspects of two experiments investigating the effect of vine spacing (Table 1) on yield, grape and wine composition, and water use. After three harvests, a close planted vineyard in Coonawarra had yielded in excess of three times the weight of fruit harvested from a standard spaced vineyard. At harvest 1989, close planting resulted in significantly less fruit per vine and lighter bunches due to fewer berries per bunch; berry weight was similar for both planting densities. There were in excess of three times more shoots per hectare on close planted vines compared with that of conventionally spaced vines, but approximately 16 more shoots and three times the weight of prunings per vine on widely spaced vines. At pruning 1989, vines at either spacing had between 31 and 33 buds per metre retained as two-bud spurs or about 204 000 buds per hectare for close planted vines and about 93 000 buds per hectare for conventional spacing.

Results presented in 1989 from the Barossa experiment were preliminary as the 1989 crop was the first to be harvested. There was little difference in yield between rootstocks at the closest spacing. At the intermediate spacing, vines on 420A rootstock had significantly less fruit than the other two stocks, while at the wide spacing vines, on K51-40 rootstock yielded more fruit than the other two stocks. All vines were pruned to about 30 buds during 1989 which resulted in close planted vines having in excess of five times more buds per hectare retained compared with that of widely spaced vines. Vines grafted to 420A had the lowest weight of prunings at all spacings. In each growing season, shoot growth was trained vertically between moveable sets of paired foliage wires. Weed growth on the soil surface was mown in early spring prior to the application of a contact herbicide and a low rate of soil residual herbicide to maintain a bare soil surface during the growing season.

Table 1. Treatments employed in the Shiraz vine spacing trial at Nuriootpa

	Narrow	Spacing Intermediate	Wide
Row spacing (m)	1.50	2.50	3.50
Vine spacing (m)	0.76	1.25	1.75
Vines/ha	8889	3200	1633

Since 1989, data collection has continued for both experiments, although small-lot winemaking with fruit from the Coonawarra experiment finished after the 1991 vintage. The fruit from Nuriootpa has not yet been subjected to small-lot winemaking or quality evaluation.

This paper presents additional yield data collected, primarily from the Nuriootpa experiment, since 1989, including soil water depletion data and a possible explanation for the results to date.

Results

Coonawarra

Compared to the standard planting distance, the high density planting has averaged 4.5 t/ha more fruit (Figure 1), and in 1992 yielded approximately 20 t/ha compared with 14.9 t/ha from the standard planting distance. Yield per hectare from the standard planting distance has increased every year since the first harvest and is now yielding at about the district average for Shiraz. Vines at both planting densities have received the same quantity of irrigation, as overhead irrigation, each year, although the amount has varied between years, depending on seasonal conditions.

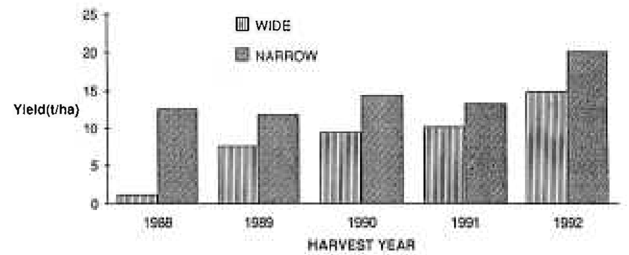

Figure 1. Yield for harvest years 1988/92 for Shiraz vines at Coonawarra.

Barossa

1. Harvest components

Widely spaced vines yielded more fruit per vine than closely planted vines (Figure 2) in each of the four years harvested, and in 1992 yielded more than three times more fruit per vine. Yield per vine was significantly higher at all planting densities in 1992 compared with that of the previous three years. All vines have been pruned to the same number of buds per metre of wire for the last three years and will be maintained at this level. Except for the 1992 harvest, closely spaced vines have yielded about 2 kg per vine which was the

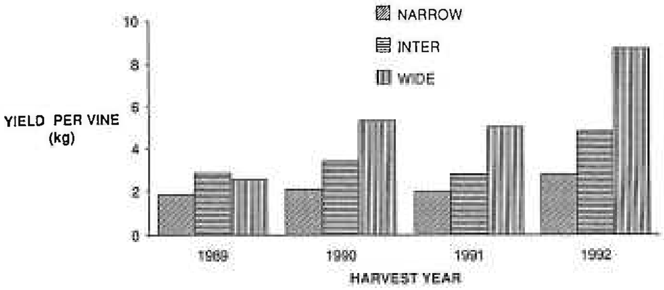

Figure 2. Yield of Shiraz vines planted at three densities in the Barossa Valley

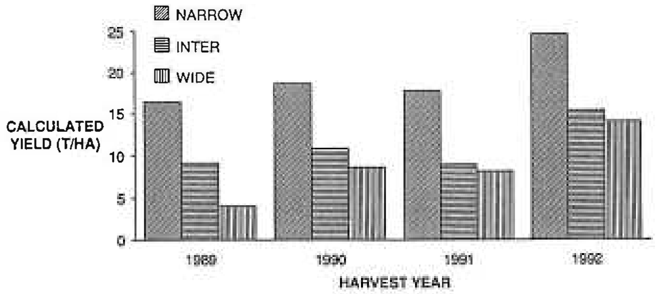

Figure 3. Calculated yield of Shiraz vines planted at three densities in the Barossa Valley

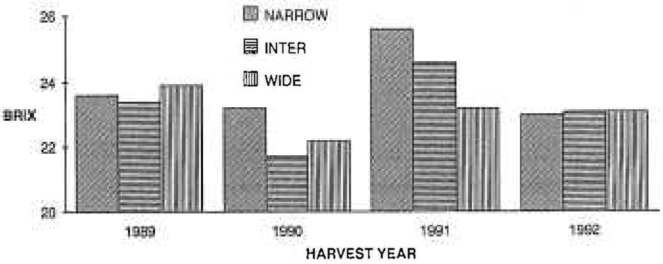

Figure 4. Total soluble solids in juice of Shiraz fruit at harvest from vines planted at three densities in the Barossa Valley

initial goal. In comparison, vines at intermediate density have yielded on average 3.7 kg per vine and widely spaced vines approximately 6.3 kg per vine. Expressed as a derived yield per hectare (Figure 3), closely planted vines have yielded between 1.7 and 2.2 times more fruit than widely spaced vines or approximately 10 t/ha more fruit. Vines planted at the intermediate distance of 2.5 m by 1.25 m have yielded more fruit per hectare than widely spaced vines, but less than closely spaced vines. There was no effect of vine density on berry weight in each year (data not presented), although there were differences between years. Berries were always less than 1 g fresh weight at harvest.

Planting density did not affect the Brix of fruit (Figure 4) at harvest in 1989 and 1992. In the other two seasons, fruit from closely planted vines was riper than fruit from widely spaced vines. Fruit from vines planted at the intermediate density were of similar maturity to that from widely spaced vines in one of these two years and of similar Brix in the other.

2. Soil water

Neutron probe access tubes were installed in 1988 at distances from own-rooted vine trunks listed in Table 2. There were three replicates of this configuration. In addition, tubes were installed midway between all other combinations (data not presented).

Soil water content was measured with a neutron probe on 13 separate occasions during the 1989/90 season, on 18 occasions during the 1990/91 season and on seven occasions during 1991/92. Only data for wide and narrow rows from the 1991/92 season are presented as it is the simplest to describe. Only one irrigation was applied late in the growing season and, although cooler than average, little rain was recorded between flowering and harvest. There was little difference in the overall pattern of soil water extraction (Figure 5) between widely or closely spaced vines. Widely spaced vines extracted approximately 20 mm more water from the profile than did closely spaced vines; although statistical analysis of data is not complete, this difference is likely to be nonsignificant. The effect of the single irrigation applied in mid-January was minimal. There was no decrease in soil water con-

Table 2. Location of neutron probe access tubes in each planting density

	Spacing		
	Narrow	Intermediate	Wide
Mid row	+	+	+
1/4 row	+	+	+
1/8 row	+	+	
Mid vine	+	+	+
1/4 vine	+	+	

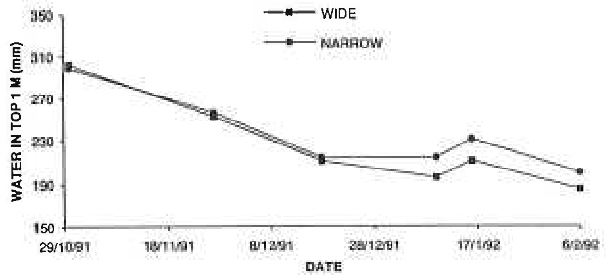

Figure 5.Soil water content for vines planted in 3.5 or 1.5 m wide rows

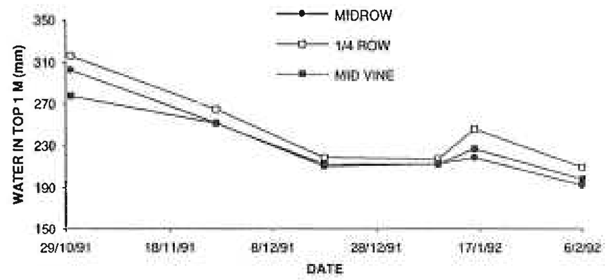

Figure 6. Soil water content for vines planted in 1.5 m wide rows

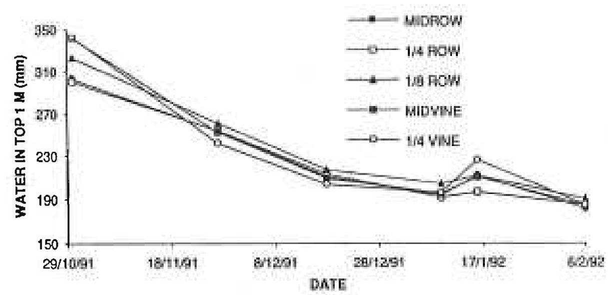

Figure 7. Soil water content for vines planted in 3.5 m wide rows

tent in narrow rows for a 20-day period between 18 December and readings taken on 9 January. Examination of soil water data from the three tubes at different distances from the vine trunk in closely spaced vines (Figure 6) suggests no water depletion across the interrow space. This is in contrast to continued soil water depletion across the inter-row area in widely spaced vines (Figure 7). This phenomenon, however, was not observed in previous years (data not presented), probably because of the additional irrigations that were applied. There was little difference in the rate of soil water depletion at each depth measured mid-row (data not presented) for either of the planting densities with the whole profile drying at a similar rate. A similar result was observed in previous years, including the first year of soil water collection.

3. Soil surface temperature

It was apparent by the 1991/92 growing season that there was a significant difference in the hours of sunlight penetrating to the vineyard floor within the different planting densities. It was hypothesized that sunlight, through an effect on soil temperature, may be influencing the rate of soil water loss mid-row. For a period of about four weeks from mid-January to mid-February, a series of thermistors was placed on the soil surface at a range of distances from the vine trunk in each planting density. The 11 sensors were programmed to record every 30 min. As sensors were not covered, they were responsive to direct sunlight. Sensors were only capable of measuring to a maximum of 50°C which, on clear days, was too low to accurately measure unshaded temperature.

Only one day's data are presented as there were few cloud-free days during the recording period. By mid-morning, sensors placed mid-row in 3.5 m wide rows were in full sunlight (Figure 8). Sensors mid-row in 2.5 m wide rows were not in full sun until about 2 pm (4 h later), and mid-row sensors received either no direct sunlight or a period of direct sunlight of less than one hour. By sunset all sensors recorded a similar temperature. No measurements were taken of sunlight incidence in the fruiting zone.

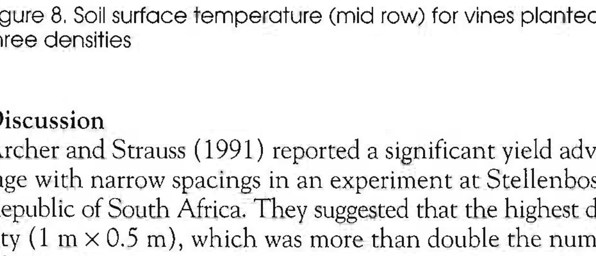

Figure 8. Soil surface temperature (mid row) for vines planted at three densities

Discussion

Archer and Strauss (1991) reported a significant yield advantage with narrow spacings in an experiment at Stellenbosch, Republic of South Africa. They suggested that the highest density (1 m × 0.5 m), which was more than double the number of vines per hectare of the closest spacing reported here, uneconomic because of the high establishment cost. The yield response to increasing vine density in the experiment reported was greater than that of Archer and Strauss (1991), but this was probably a result of different pruning levels. In this experiment, all vines were pruned to 40 buds per metre of wire resulting in 2 to 4 times more buds per hectare compared with the 65 000 buds per hectare for all spacings used by Archer and Strauss (1991). Differences in budburst resulted in 25 shoots per metre for closely spaced vines, 23 for intermediate and 22 for widely spaced vines, which all are higher than the 15 shoots per metre recommended by Smart *et al.* (1990) for the production of high yields and improved fruit composition.

The small difference in sugar concentration of fruit from vines at the three planting densities (Figure 4) is in agreement with the findings of Archer and Strauss (1991) who reported earlier ripening with closely spaced vines. They suggested this response was probably a function of better microclimate conditions, such as homogeneity of leaf surface and leaf area:fruit mass relationships. Although no wine assessment has been done on fruit from Nuriootpa, there should be an improvement in quality as reported by Strauss and Archer. The dimensions of the Nuriootpa experiment approximately meet the five vine ideotype principles suggested by Smart *et al.* (1990) and, in addition, meet the fifth principle; the ability to be mechanized. The Coonawarra demonstration planting is now machine pruned and mechanically harvested. The current major labour input is foliage manipulation, but this could also be mechanized as suitable equipment is now available in Australia.

Lascano *et al.* (1992) reported that in a three-year-old Chardonnay vineyard, planted at 3.05 × 1.22 m, the ratio of E to ET was 0.77; more water was lost through evaporation from the soil surface than was transpired by the vines. They suggested the high soil evaporation was due, in part, to the considerable portion of the soil surface that over the duration of the experiment was not shaded by the plant canopy and to the irrigation method which wet the whole vineyard floor. Data presented here for soil surface temperature demonstrated, in a similar manner, that a significantly greater proportion of the vineyard floor of widely spaced rows was unshaded compared to that of narrow rows. Neutron probe data indicate the mid-row area of widely spaced vines was drying at about the same rate as that of closely spaced vines. A similar pattern had been observed in the previous years of trial establishment when there would have been little root development mid-row in widely spaced rows. It is not possible to quantify the amount of lateral movement of water from the mid-row area to zones of root extraction, but is likely to be low in the clay textured subsoil. It is hypothesized that in widely spaced rows at least 50 % of the soil water is lost through evaporation; narrow rows which result in much of the vineyard floor being shaded significantly reduces this evaporation component allowing this soil water to be exploited by the vine in growing additional fruit (Figure 9). Reducing soil evaporation by the use of thick straw mulch, resulted in more soil water being available for plant growth and doubled pruning weight (McCarthy, unpublished data), but on a restrictive single wire trellis, excessive shading resulted in lower fruitfulness.

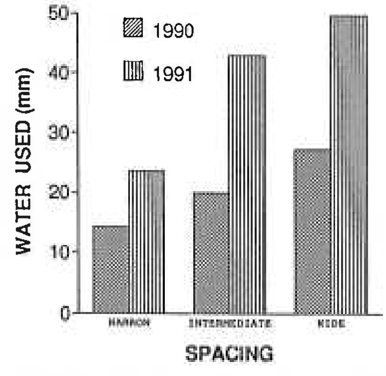

Figure 9. Water (mm) used per tonne of fruit

Both the data reported here and the results from the Stellenbosch experiment highlight the significant increase in yield per hectare with no delay in maturity and no additional irrigation; the Stellenbosch experiment was conducted under dryland conditions. As the availability of prime viticultural land (soil and water) decreases, grapegrowers will need to optimize the productivity from existing areas. Increased yield, however, can not be at the expense of fruit quality. Although no assessment of wine quality has been made on the Nuriootpa experiment, Archer and Strauss (1991) reported that closer vine spacing will have important economic advantages as a result of higher yield per hectare as well as better wine quality. It is significant that these authors suggested that under the conditions of their experiment a vine spacing resulting in between 1.0 and 2.0 m^2 per vine was optimum which covers the range of 1.12 m^2 per vine for the closest spacing used in the current experiment. Both sites are climatically similar. Archer and Strauss warn that under more fertile conditions, more vegetative growth leading to denser canopies and a decline in wine quality, is likely. The Nuriootpa site would probably be classified as of moderate fertility compared with other soils that are used for viticulture in Australia. Higher vegetative growth could also be caused by incorrect choice of rootstock, excessive irrigation or high growing season rainfall as occurs in many other grapegrowing regions of the world where no 'box' effect is obtained (Archer 1987).

The importance of the correct choice of rootstock, where high vine densities are to be employed, is emphasized in the response of the rootstock 420-A (data not presented). At the highest density used in this experiment, Shiraz grafted onto 420-A yielded as much fruit in 1992 as vines on their own roots, were of similar ripeness, and had less than half the weight of prunings and smaller berries suggesting that the fruit may have been of higher quality. Less fertile conditions may conversely result in excessive water stress as a result of differences in root distribution and soil water extraction patterns (Archer and Strauss 1985, 1989). It is, therefore, apparent that while higher vine densities will result in higher yields and probably improved wine quality, as a result of the necessary foliage management, very careful selection of site, rootstock, soil and water management will be required to achieve these goals. A detailed financial analysis of establishment and maintenance costs would also be necessary before planning such a vineyard.

References

Archer, E.; Strauss, H.C. Effect of plant density on root distribution of three-year-old grafted 99 Richter grapevines. S. Afr. J. Enol. Vitic. 6: 25-30; 1985.

Archer, E. Effect of plant spacing on root distribution and some qualitative parameters of vines. Lee, T.H., ed. Proceedings of the sixth Australian wine industry technical conference; 14-17 July 1986; Adelaide, SA. Adelaide, SA: Winetitles; 1987: 55-58.

Archer, E.; Strauss, H.C. The effect of plant spacing on the water status of soil and grapevines. S. Afr. J. Enol. Vitic. 10: 49-58; 1989.

Archer, E.; Strauss, H.C. The effect of vine spacing on the vegetative and reproductive performance of Vitis vinifera L. (cv. Pinot Noir). S. Afr. J. Enol. Vitic. 12: 70-76; 1991.

Lascano, R.J.; Baumhardt, R.L.; Lipe, W.N. Measurement of water flow in young grapevines using the stem heat balance method. Am. J. Enol. Vitic. 43: 159-165; 1992.

McCarthy, M.G. Planting density, irrigation and rootstock effects on the plant and soil. Williams, P.J.; Davidson, D.M.; Lee, T.H., eds. Proceedings of the seventh Australian wine industry technical conference; 13-17 August 1989; Adelaide, SA. Adelaide, SA: Winetitles; 1990: 66-68.

Smart, R.E.; Dick, J.K.; Gravett, I.M.; Fisher, B.M. Canopy management to improve grape yield and wine quality — principles and practices. S. Afr. J. Enol. Vitic. 11: 3-17; 1990.